

# Electrically Millicharged Neutrino in Media

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## Abstract

On the basis of nonzero neutrino electromagnetic properties, we consider a problem of electrically millicharged neutrino energy spectra in a magnetized matter. It is shown that in this case neutrino energies are quantized. These phenomena can be important for astrophysical applications.

**Keywords:** massive neutrino, neutrino electromagnetic properties, relativistic wave equations, exact solutions

Within the Standard Model a massless neutrino has trivial (or vanishing) electromagnetic properties. However, a massive neutrino <sup>1</sup> even in the easiest generalization of the Standard Model should have non-trivial electromagnetic properties [1]. For a recent review on neutrino electromagnetic properties see [2]. A massive neutrino can also be electrically charged (millicharged) particle in a class of more general theoretical models [3]. The most severe experimental constraints on the electric charge of the neutrino,  $q_\nu \leq 10^{-21}e$  [4].

We consider a millicharged massive neutrino propagating in nonmoving magnetized medium composed of neutrons using the modified Dirac equation for the neutrino wave function exactly accounting for the neutrino interaction with matter [5] where we should substitute the neutrino momentum  $p^\mu$  for the "extended" momentum  $p^\mu \rightarrow p^\mu - q_\nu A^\mu$  to account for the neutrino interaction with magnetic field:

$$\left\{ \gamma_\mu (p^\mu - q_\nu A^\mu) + \frac{1}{2} \gamma_\mu (1 + \gamma^5) f^\mu - m \right\} \Psi(x) = 0,$$

where  $q_\nu$  is a millicharge of the neutrino. Here we choose that the electromagnetic field and effective matter potential are  $A^\mu = (0, -\frac{\gamma^B}{2}, \frac{x^B}{2}, 0)$ ,  $f^\mu =$

$-Gn(1, 0, 0, 0)$ , where  $G = \frac{G_F}{\sqrt{2}}$ ,  $n$  is matter number density. Than we can get the neutrino energy spectrum,

$$p_0 = \frac{Gn}{2} + \varepsilon \sqrt{\left(-\frac{Gn}{2} + mT^0\right)^2 + m^2}, \quad \varepsilon = \pm 1,$$

where  $T^0 = \frac{s'}{m} \sqrt{p_3^2 + 2q_\nu BN}$ ,  $s' = \pm 1$  are eigenvalues of the spin operator  $\hat{T}^0 = \frac{1}{m} \boldsymbol{\sigma}(\hat{\mathbf{p}} - q_\nu \mathbf{A})$  that commutes with the corresponding Hamiltonian,  $N = 0, 1, 2, \dots$

From this spectrum it follows that the effect of the neutrino trapping on circular orbits in magnetized matter exist that can be important for astrophysical applications.

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## References

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<sup>1</sup>There is no doubt that the recent studies of flavour conversion in solar, atmospheric, reactor and accelerator neutrino fluxes give strong evidence for non-zero neutrino mass.